useful for an independent verification of dosimetric data and tables used for manual calculations.
These results also highlight the need for a better understanding of dose distributions associated with irregular and curved surfaces, through numerical modelling such as Monte Carlo calculations. Further investigation is thus necessary to understand these effects and to improve target coverage in pelvic IOERT.
1. Ciocca M, Piazzi V, Lazzari R, et al. Real-time in vivo dosimetry using micro-MOSFET detectors during intraoperative electron beam radiation therapy in early-stage breast cancer. *Radiother. Oncol.* 2006;78(2):213-6.

PD-0573

Dosimetry verification of an applicator system for intraoperative radiation therapy by Monte Carlo simulation

A. Nevelsky[1], E. Borzov[1], R. Ber-Deroma[1], I. Orion[2]
[1]*Rambam Health Care Campus Faculty of Medicine Technion, Oncology, Haifa, Israel*
[2]*Ben-Gurion University, Nuclear Engineering, Beer-Sheva, Israel*

Purpose/Objective: Design and dosimetry characteristics of a commercial applicator system for intraoperative radiation therapy (IORT) utilizing ELEKTA Precise accelerator have been previously reported. The system is geometrically more complex than the standard electron applicators used for external beam therapy. Moreover, the geometry is different from the reference conditions used in various dosimetry protocols. The purpose of this work is to validate the measured dosimetry data by Monte Carlo (MC) simulations.
Materials and Methods: An IORT hard-docking commercial system (Arplay Medical) includes PMMA cones with different diameters and a set of secondary lead collimators. The telescopic device allows changing of source to surface distance (SSD). The inner diameters of the available cones are 40, 50, 60 and 80 mm. 6, 9 and 12 MeV beams from Elekta Precise linac are used for IORT treatments. The EGSnrc code package was used for MC simulation. First, the incident electron beam parameters (energy spectrum, FWHM) were adjusted to match the measured data (depth doses and profiles) at SSD=100 cm for 14x14 standard electron applicator. These parameters were then used to calculate depth doses, dose profiles and output factors with the IORT applicator system. BEAMnrc code was used to generate the phase-space file in a plane at the IORT cone end. This file was used in DOSXYZnrc code to calculate PDDs, profiles and output in a water phantom at SSD= 100 cm for each combination of cone diameter and beam energy. MC calculations were compared with the available set of measurements used in clinical practice.
Results: The results of our Monte Carlo calculations were found to be in general agreement with the measurements, providing a promising tool for further studies of dose distribution calculations in IORT. For all combinations of energy and cone diameter, the calculated depth doses were within 2%/1mm agreement with the measurements and calculated profiles were within 3%/1mm agreement with the measurements. Calculated output factors were within 3% agreement with the measurements.
Conclusions: The measured dosimetry data used for IORT calculations have been validated by MC simulations. This work also indicates that simulations can complement and/or replace experimental measurements for design improvements of an IORT system.

PD-0574

Dose distributions in pelvic intra-operative radiation therapy (IOERT)

F. Costa[1], S. Sarmento[1], O. Sousa[2]
[1]*Instituto Português de Oncologia do Porto, Centro de Investigação, Porto, Portugal*
[2]*Instituto Português de Oncologia do Porto, Serviço de Radioterapia, Porto, Portugal*

Purpose/Objective: Rectal cancer is the second most frequently treated tumour with intra-operative radiation therapy (IOERT) in Europe[1] , the first being breast cancer. Due to the complex anatomy of the pelvic region, understanding the IOERT dose distribution is particularly challenging. This work was prompted by a preliminary attempt to perform and to interpret in vivo measurements, and aims to shed some light on how the irradiation geometry affects the dose distribution in pelvic IOERT.
Materials and Methods: To determine the effect of irregular geometries on the dose distribution, a methodology using Gafchromic EBT3 films for 2D dose distributions determination, parallel to the incident beam was validated through comparison with water phantom measurements.
Data of anatomical region irradiated, applicator diameter and bevel angle was obtained from 21 pelvic IOERT procedures. This data was combined with anatomical models and photographs taken during in vivo measurements. Schematic models were made of the more frequent irradiation scenarios in pelvic IOERT, and relevant phantom equivalents were constructed. The corresponding dose distributions were obtained, and compared to those in conventional irradiation geometry (flat surface, parallel to applicator bevel).
Results: The most frequently used bevel angle is 45°. A curved (concave) irradiation surface is frequent in pelvic IOERT. Haematic fluid build-up is also problematic in this area. Applicator positioning can be challenging when none of the available applicators is an ideal fit for the surface to be irradiated. This results in air gaps caused by non-parallel alignment of surface and applicator edges. Additionally, the surface to be irradiated may have irregularities in contour as well.
Concave irradiation surfaces affect the dose distribution, relative to the one obtained in water. Air gaps due to non parallel alignment of the applicator seem to have little influence, although the effect of a different angle of incidence is clearly visible. Irregularities in contour may create hotspots nearby, as shown by the arrow in Figure 1.

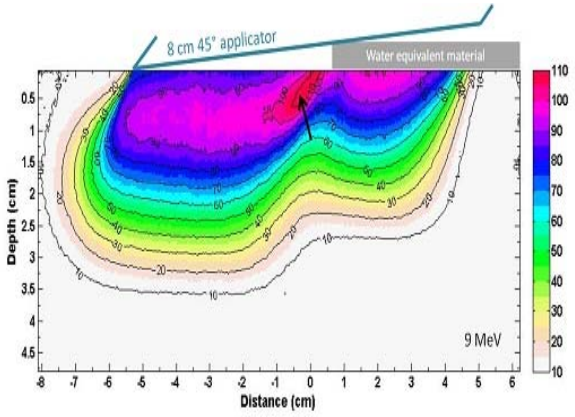

Figure 1. Example of dose distribution in phantom

Conclusions: Dose distributions in pelvic IOERT are complex, non-homogeneous and hard to predict. The constructed phantom models allow us to simulate dose distributions, with good visualization of the clinically relevant effects, but with a controlled geometry. The results obtained confirm that

irregular and curved surfaces can significantly alter the dose distribution. A better understanding of these effects is necessary to assess target coverage in pelvic IOERT, and interpret any in vivo measurements.

1. Krengli M, Calvo F a, Sedlmayer F, et al. Clinical and technical characteristics of intraoperative radiotherapy. Analysis of the ISIORT-Europe database. *Strahlentherapie und Onkol*. 2013;189(9):729-37.

Poster Discussion: RTT

PD-0575

The dosimetrical advantage of prone position on a belly board for rectal cancer: does it still hold with VMAT?

J. Verstraete[1], I. Joye[1], C. Bertoncini[2], T. Depuydt[1], K. Haustermans[1]

[1]*University Hospital Gasthuisberg, Radiation Oncology, Leuven, Belgium*

[2]*Hospital Italiano, Radiation Oncology, Buenos Aires, Argentina*

Purpose/Objective: The aim was to evaluate whether prone position on a belly board for rectal cancer radiotherapy is still beneficial when highly-conformal volumetric modulated arc therapy (VMAT) is applied. Additionally, the feasibility of moderate dose escalation with VMAT was investigated.

Materials and Methods: Eleven patients with stage II/III rectal cancer were prospectively enrolled. Each patient underwent a planning CT in both prone and supine position. For prone positioning, a belly board was used (MacroMedics® Pelvic Prone Board™).

To evaluate the dosimetrical benefit of prone vs. supine position, VMAT plans (2 arcs of 358°) were created for both treatment positions. A dose of 45 Gy in 25 fractions was prescribed. Plans were considered acceptable if ≥95% of the planning target volume (PTV) received ≥95% of the prescribed dose and if Dmax was ≤107% of the prescribed dose. For comparison of prone and supine, an average DVH over all patients was created by calculating for each structure the mean relative volume in 10 cGy absolute dose bins.

To investigate the feasibility of moderate dose escalation, only the prone scans were used and 3D-conformal radiotherapy (3D-CRT) plans (45 Gy in fractions of 1.8 Gy) were compared with VMAT plans (50 Gy in fractions of 2 Gy). The homogeneity index (HI) of the PTV was defined as [(D2-D98)/$D_{prescribed}$ x 100] and the conformity index (CI) as V95/PTV_{volume}. Statistical analyses were performed using the Wilcoxon signed-rank test; a p-value ≤ 0.05 was considered statistically significant.

Results: While the PTV parameters were similar, prone positioning reduced the V15 of the small bowel (median 64.4 cc vs. 194.8 cc; p = 0.008), the V15 of the large bowel (median 38.5 cc vs. 71.3 cc; p = 0.006) and the V15 of the bowel bag (median 433.4 cc vs. 762.2 cc; p = 0.003) compared to supine using VMAT (Table 1). The V45 of all bowel structures was also lower in prone position, but this was not statistically significant.

Moderate VMAT dose escalation up to 50 Gy does not lead to an increased dose to the organs at risk compared to 3D-CRT up to 45 Gy. The V15 of the bowel bag and the V40 of the bladder were significantly lower with VMAT 50 Gy compared to 3D-CRT 45 Gy (median 445.2 cc vs. 562.6 cc, p = 0.003; median 32.8 cc vs 47.1 cc; p = 0.003 respectively). 3D-CRT plans had a higher CI compared to VMAT (median 1.00 vs. 0.96; p = 0.003). The PTV dose homogeneity was better in the 3D-CRT plans compared to the VMAT plans (median 8.13 vs. 9.48; p = 0.006).

Table 1: Dosimetrical comparison of VMAT supine vs. VMAT prone and of 3D-CRT prone (45 Gy) vs. VMAT prone (50 Gy); median (range)

Volume	Dose parameter	VMAT supine (450y)	VMAT prone (450y)	p-value	3D-CRT prone (450y)	VMAT prone (500y)	p-value
PTV	$D_{98\%}$ (Gy)	37.3 (33.2 – 39.3)	35.2 (25.5-37.5)	0.120	42.2 (17.8 – 42.8)	39.1 (28.3 – 41.6)	0.859
	$D_{2\%}$ (Gy)	47.3 (47.0 – 47.5)	47.4 (47.0 – 47.9)	0.285	48.1 (46.5 – 48.2)	52.7 (52.2 – 53.2)	**0.003**
	D_{mean} (Gy)	45.0 (44.7 – 45.4)	45.0 (45.0 – 45.3)	0.176	45.3 (45.0 – 45.9)	50.0 (50.0 – 50.4)	**0.003**
	CI	0.96 (0.95 – 0.98)	0.96 (0.95 – 0.99)	0.237	1.00 (0.99 – 1.00)	0.96 (0.95 – 0.98)	**0.003**
	HI	9.51 (8.33 – 11.07)	9.31 (8.42 – 10.81)	0.213	8.13 (5.47 – 9.08)	9.48 (8.29 – 12.5)	**0.006**
	Volume	1258.1 (1000.5 – 1627.2)	1347.2 (1094.6 – 1648.4)	0.062			
Small bowel	V15	194.8 (0.0 – 780.4)	64.4 (0.0 – 744.2)	**0.008**	95.7 (0.0 – 764.6)	66.4 (0.0 – 753.5)	0.208
	V45	1.7 (0.0 – 132.6)	0.2 (0.0 – 133.5)	0.779	28.9 (0.0 – 563.4)	10.1 (0.0 – 271.5)	0.484
	Volume	348.0 (21.6 – 848.4)	154.8 (0.0 – 905.9)	**0.010**			
Large bowel	V15	71.3 (12.3 – 265.1)	38.5 (0.9 – 178.6)	**0.006**	41.4 (2.7 – 201.8)	38.9 (1.0 – 180.5)	0.006
	V45	2.6 (0.0 – 13.9)	1.0 (0.0 – 26.2)	1.000	15.1 (0.1 – 44.2)	11.9 (0.0 – 59.3)	0.534
	Volume	117.7 (16.4 – 394.5)	66.3 (14.2 – 236.4)	**0.013**			
Bowel bag	V15	762.2 (386.6 – 1341.1)	433.4 (62.4 – 888.6)	**0.003**	562.6 (109.8 – 922.7)	445.2 (66.2 – 906.5)	**0.003**
	V45	37.3 (6.9 – 169.02)	28.1 (7.4 – 153.4)	0.594	160.0 (33.0 – 398.7)	134.9 (21.7 – 312.8)	0.062
	Volume	1340.7 (880.1 – 2649.1)	1029.0 (438.7 – 1369.9)	**0.008**			
Bladder	V40	26.9 (2.5 – 54.3)	22.0 (0.0 – 41.0)	0.374	47.1 (2.2 – 119.7)	32.8 (0.0 – 59.0)	**0.003**
	D_{max} (Gy)	46.1 (45.1 – 47.0)	46.1 (37.2 – 47.1)	0.657	46.7 (44.9 – 48.1)	51.3 (41.3 – 52.4)	**0.008**
	Volume	111.0 (59.3 – 224.1)	92.7 (42.0 – 191.5)	**0.005**			

Legend: CI = conformity index; HI = homogeneity index; PTV = planning target volume; VMAT = volumetric modulated arc therapy; 3D-CRT = 3D-conformal radiotherapy. Volumes are in cc. Bold values are statistically significant.

Conclusions: Even with highly-conformal radiotherapy techniques as VMAT, prone position with belly board remains beneficial for the dose to the bowel structures. Moderate dose escalation with VMAT up to 50 Gy does not increase the V15 and V45 of the bowel structures compared to 3D-CRT up to 45 Gy.

PD-0576

Quantification of dosimetric impact of rotational displacements in head and neck VMAT radiotherapy

J. Hayes[1], M. McGarry[1], G. Perkins[1], R.W. Hammoud[1], S. Paloor[1], S. Divakar[1], M. Riyas[1], B. Benson[1], P. Petric[1], N. Al Hammadi[1]

[1]*NCCCR, Radiation Oncology, Doha, Qatar*

Purpose/Objective: To quantify and to assess the dosimetric significance of rotational displacements in head and neck patients planned with VMAT, in order to establish a process development pathway for the management of rotational displacements.

Materials and Methods: Initial quality assurance of the commercially available IGRT software (OBI™) was performed. Varying permutations of the offline auto match process and weightings (Volume of Interest (VOI), Structure VOI (sVOI) and Intensity Range) were assessed in Six degrees of freedom (6DoF), in order to determine the optimum method for rotational quantification across twelve patients with various tumour sites. To determine thresholds of dosimetric impact for rotational setup errors, simulated rotational displacements were created on the Planning CT images (PCT) for each patient. Using commercially available software (MIMS ™) the PCT images were rotated around the isocentre incrementally from 1 to 5 degrees – this was done for combined and single axis rotational displacements. The manipulated image sets were then exported back to the ECLIPSE™ treatment planning system to determine the dosimetric consequences of rotations on both the PTV and the Organs At Risk (OAR).

Results: Regardless of Intensity Range employed, results demonstrate that using PTV as the sVOI is preferential compared to using OAR sVOI or matching without the inclusion of rotations (Table 1). On the virtually rotated PCT images, both combined and single axis simulations demonstrated more variance in dose to the OAR when compared with PTV. D98% for the PTV showed noticeable difference when compared to the PCT, varying by 11.3% and 13.3% for combined rotations of +3 and -3 degrees, respectively. D2% for the PTV showed little or no variation (Figure 1A). Spinal Cord Planning Organ at Risk Volume (PRV) (3mm margin) showed the most noticeable dose difference with D1cc variation of 15.54% and 12.65% at combined rotations of +/-1 degree, respectively. Spinal cord (SC) is